STATE PAVEMENT TECHNOLOGY CONSORTIUM

A Collaboration of:

CalTrans MnDOT TxDOT WSDOT

BENEFIT / COST ANALYSIS

(RETURN ON INVESTMENT)

STATE MATERIALS LABORATORY
ENVIRONMENTAL AND ENGINEERING PROGRAMS
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
July 9, 2003

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Benefits of Materials, Pavement and Construction Research

INTRODUCTION

California, Texas, Minnesota and Washington are among the leading states in the research, development and deployment of advanced pavement technology. Each State Department of Transportation (DOT) has a continuing research and development program designed to improve its pavement design, rehabilitation, construction, and maintenance procedures. Each has long-standing research relationships with universities within that State, and all State DOTs have made substantial investments in research equipment and facilities. These programs have produced significant improvements in pavement technology resulting in improved pavement practices. Such practices aid all road owning public agencies in each state, and also benefits university education.

The sharing of information between researchers and practitioners in these states can be of substantial mutual benefit. These benefits include, but are not limited to: joint research and development programs of common interest; leveraging scarce funds and maximizing the use of existing expertise and research facilities; accelerated technology transfer of new knowledge among the participating states; identification of emerging critical issues; and educating transportation professionals on the latest technological advances.

Formed in 1999 as a pooled-fund study, the State Pavement Technology Consortium (SPTC) collaboratively exploits pavement research to improve each member's department of transportation. To support this effort, each of the four State DOTs contributed $15,000 per year for four years. This funding supported travel for site visits to each of the four states, the preparation of formal minutes, and minor coordinating costs incurred by the lead state (Washington). Additional contributions funded individual research projects, as selected by the SPTC.

What has four years of pooled-fund effort produced? For WSDOT, the total cost has been $164,490 (travel plus research projects) and the total benefit has been $67,550,000, for a benefit/cost ratio of **432** (Note: benefit/cost ratios are normally acceptable if they exceed 1.0, denoting a positive benefit for a given cost). This extraordinary ratio confirms the exceptional return from this investment: our modest investment has been returned over four-hundredfold. Given the very modest investment, from a state with a very modest research program, this return is exceptional and important. WSDOT is recognized nationally and internationally for our excellence, particularly for our pavements program. Leveraging our very small research investment to return such exceptionally large value is both a hallmark of our program and a necessity. Without such leverage we could not maintain our highway pavement program at our current level of investment. The results **(B/C = 432!)** speak for themselves.

REPORT PURPOSE AND ORGANIZATION

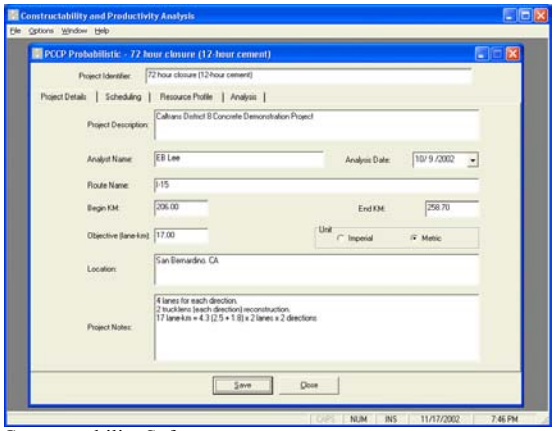
The purpose of this report is to document the cost benefits that have resulted from the various research activities conducted through the SPTC. This report is organized according to SPTC

research, Caltrans research, NCAT research, and other shared research. The attached appendices describe the basis for the calculation of benefits.

STATE PAVEMENT TECHNOLOGY CONSORTIUM RESEARCH PROJECTS

Constructability Analysis Software. This software provides a construction analysis tool that considers several pavement design options along with construction scheduling, resource constraints, traffic management, and user-delays. This simulation software will assist transportation agencies in quickly developing constructability strategies to compare all options available for a rehabilitation or reconstruction project. The functions of the software are: (1) analyze information from past construction projects, to aid in predicting the productivity of future projects, (2) identify construction productivity constraints so that policies can be developed to mitigate the effects of the constraints, (3) support selection of optimized rehabilitation processes to maximize construction productivity and minimize traffic delays, and (4) estimate the optimized production for rehabilitation and reconstruction projects, and the associated hours of closure required to complete a project. The California DOT reconstructed a portion of I-10 in Pomona, California ($15.9 million to rehabilitate 3.3 miles from 10 PM Friday night until 5 AM Monday morning, on a facility with 240,000 ADT), to determine the necessary inputs and model development for this software. It is anticipated that this software will be further enhanced to also include typical rehabilitation treatments (AC overlays, dowel bar retrofit, etc.). The expected benefit to WSDOT is an improved procedure for analyzing rapid construction of heavily trafficked roadways. It is anticipated that this research study will result in a WSDOT cost savings of approximately $5,000,000 (see Appendix 1).

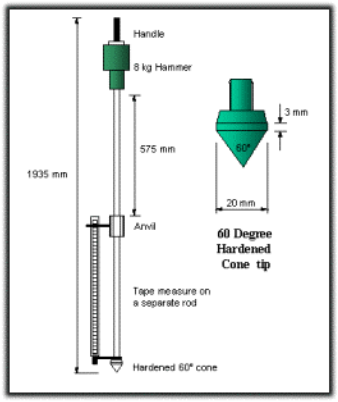
I-710 – Reconstruction Project



Constructability Software

Improved pavement field characterization. With the increasing national emphasis on and direction toward mechanistic-empirical pavement design and analysis, improved pavement field properties will become more important. This is further supported by the increasing awareness of the significant role that construction variability plays with respect to pavement performance and the resulting need to characterize pavements via actual field obtained properties. It is anticipated that this research study will result in a WSDOT cost savings of approximately $200,000 (see Appendix 2).

Falling Weight Deflectometer



Dynamic Cone Penetrometer

Longitudinal joint compaction in hot-mix asphalt pavement. When placing hot-mix asphalt concrete, paving the full width of the pavement in a single pass is usually impossible; therefore most hot-mix asphalt pavements contain longitudinal construction joints. These construction joints can often be inferior to the rest of the pavement and can eventually cause an otherwise sound pavement to deteriorate. This research was being conducted by the Texas Department of Transportation (TxDOT) and was expanded to incorporate hot-mix asphalt samples obtained from the other three states. Texas determined that the cause of this problem was due to the significantly lower density around the longitudinal joint. It is anticipated that this research study will result in a WSDOT cost savings of approximately $4,000,000 (see Appendix 3).

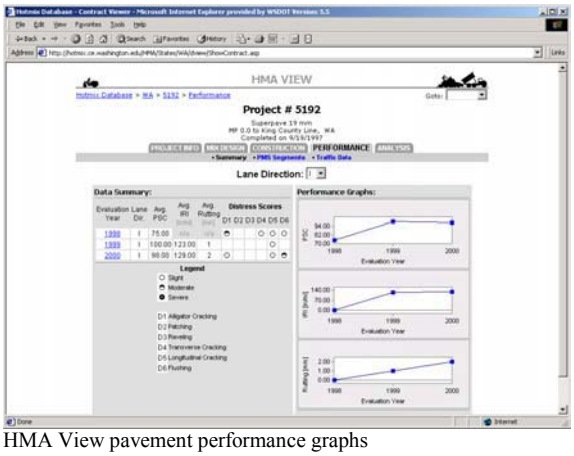
Longitudinal joint distress

Longitudinal joint distress – crack sealed

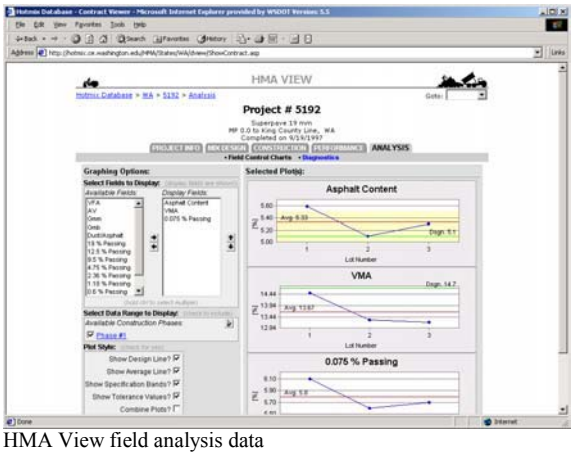
HMA View. As a result of the Strategic Highway Research Program (SHRP), most states have been evaluating Superpave as a new mix design procedure. In addition, there is a tremendous amount of research ongoing and planned to assist agencies in evaluating Superpave, particularly in the areas of design and construction. The next logical step is a method for evaluating and measuring actual field performance. HMA View is an on-line analysis tool for viewing design, construction, and performance characteristics of hot-mix asphalt pavements. This project, which is being conducted by the University of Washington, began with the SPTC, but has been quickly adopted (and dramatically improved) by work done for the Maryland DOT (considerable enhancements at no cost to WSDOT). This analysis tool is the link between mix design, construction, and pavement performance. The primary benefits of this analysis tool is the ability to document how aggregate gradation, asphalt content, in-place density, etc., relates to pavement performance, and the ability to troubleshoot (in real time since this tool is available on-line) with

the Project Office, Contractor, Construction, and Materials Lab to resolve issues during construction of a pavement. It is anticipated that this research study will result in a WSDOT cost savings of approximately $3,000,000 (see Appendix 4).

HMA View can be accessed at - http://hotmix.ce.washington.edu/hma/



HMA View pavement performance graphs



HMA View field analysis data

CALTRANS RESEARCH PROJECTS

The California Department of Transportation (Caltrans) is currently spending $5,000,000 per year on pavement related research. In the five years of the SPTC, this implies that the other three states have been able to benefit from the Caltrans research program of $25,000,000. Though all Caltrans research projects are not listed here, Caltrans has been extremely willing to provide all states with the research results. It is envisioned that WSDOT, in the near future, will be reviewing and implementing, where appropriate, a number of Caltrans research findings.

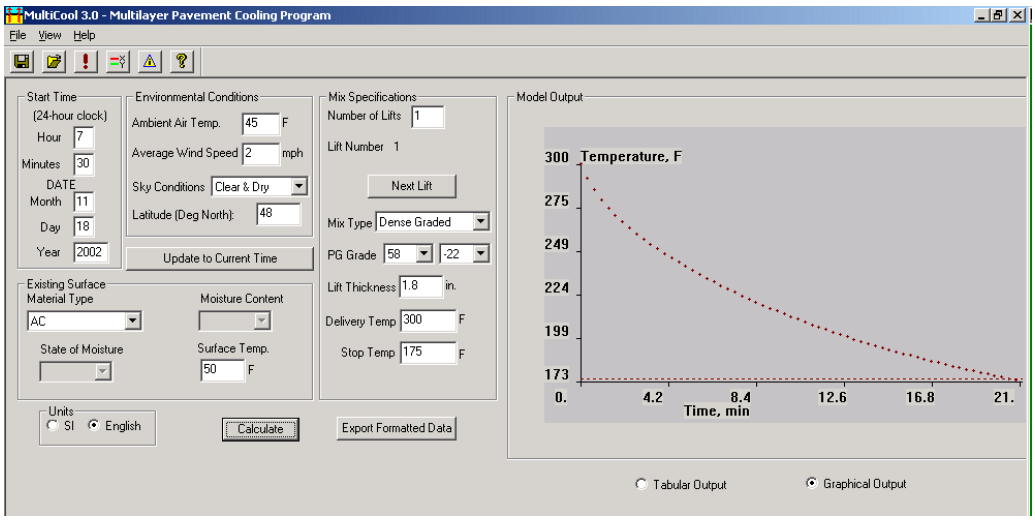
Dowel Bar Retrofit. The objective of this research is to evaluate the performance of an in-place pavement with and without dowel bar retrofit. This accelerated pavement testing is being performed in Ukiah, California with the Caltrans heavy vehicle simulator. The heavy vehicle simulator is a mobile testing machine used to subject roads to accelerated trafficking. It can simulate ten years of traffic in as little as two months, thus helping engineers to understand the mechanisms of road failure caused by traffic and, to some extent, by environmental factors. WSDOT has performed dowel bar retrofit for eight years and the data collected through the accelerated pavement testing will be used to verify the presumed failure mechanism and evaluate the performance of the dowel bar retrofit rehabilitation treatment. It is anticipated that this research study will result in a WSDOT cost savings of approximately $15,000,000 (see Appendix 5).

Heavy Vehicle Simulator (HVS) at Palmdale, California

Ukiah dowel bar retrofit test site

Climatic Database. The climatic data was developed to give users access to the National Oceanic Atmospheric Administration (NOAA) weather data and then allow temperature related queries. Numerous options are available to view data both graphically and in numerical formats. The database includes over 7,400 weather stations from across the United States. The climatic database will be organized so users can summarize weather information for the following purposes: pavement design or pavement materials, construction and maintenance, and forensic investigations. One of the most useful queries is that of selecting a virtual weather station. A virtual weather station is one where documented data is not available at a specific location; however, realistic weather data can be interpolated for that specific site from surrounding weather stations. Another option is that of simply providing the best local match from a weather station for any location selected. Approximately 270 first order weather stations across the United States allow more specific queries for information relevant to precipitation, relative humidity, wind speed, and cloud cover. The researchers for the climatic database are currently making modifications to the program. A beta version for WSDOT review should be available in mid May. It is anticipated that this research study will result in a WSDOT cost savings of approximately $100,000 (see Appendix 6).

Multi-Cool Software. The objective of this study was to provide a solution to the pavement heat transfer problem by means of a computer program that can be used to determine pavement temperature profiles throughout the duration of the paving operation. Use of the program can provide an optimal compaction timeframe that minimizes construction delays and improves construction efficiency. The program permits a maximum of nine pavement lifts and considers cloud cover, ambient temperature, wind speed, lift thickness, existing base material type, thermal properties, and temperature, hot-mix material type and thermal properties. It is anticipated that this research study will result in a WSDOT cost savings of approximately $1,000,000 (see Appendix 7).



Asphalt Treated Permeable Base (University of California – Berkeley). This study involved the use of the heavy vehicle simulator to evaluate asphalt concrete pavement sections containing asphalt treated permeable base. The primary results of this study indicate that the asphalt treated permeable base is susceptible to stripping due to low compaction (low density) requirements and low asphalt binder contents. Though WSDOT determined years ago to eliminate the use of asphalt treated permeable base (based more on construction difficulties), this study highlighted issues surrounding the use of asphalt treated base as well. This research confirms the decisions made by WSDOT and provides scientific justification for this decision. It is anticipated that this research study will result in a WSDOT cost savings of approximately $500,000 (see Appendix 8).

Tack Coat Benefits. As part of the asphalt treated permeable base study, the University of California – Berkeley also noted that the typical Caltrans specification did not require the placement of a tack coat between two new lifts of asphalt pavement. The use of a tack coat between new asphalt layers has been a WSDOT requirement for some time, however, often times its use has been excluded or not appropriately applied such that adhesion of the layers of asphalt has not been assured. From the Caltrans study, they were able to show that the lack of bond between the asphalt layers lead to additional fatigue cracking. This occurs since the asphalt layers acted independently from each other rather than as a thicker asphalt layer system (much like a glue-lam beam). It is anticipated that this research study will result in a WSDOT cost savings of approximately $5,000,000 (see Appendix 9).

Hydraulic Cements. As part of the Caltrans Long Life Pavement Rehabilitation Strategies, fast-setting hydraulic cements and Type I/II portland cement were evaluated under the heavy vehicle simulator. The primary purpose of this study is to determine what type of cement is need to obtain 400-psi flexural strength within 4 to 8 hours of placement. Two full-scale test sites, each approximately 690 feet in length, were constructed on State Route 14, about 5 miles south of Palmdale, California. The test site in the southbound direction included sections with different thicknesses of concrete placed on compacted granular base. The site in the northbound direction included eight inch concrete on cement treated base, with various design features: dowels, tied shoulders, and a widened lane. The results of this study indicated that certain hydraulic cements loose strength with time and that construction difficulties are encountered with hydraulic cement

concrete (primarily difficulty in placing with a paving machine and consolidating prior to hardening). Therefore, it is WSDOT's assessment that hydraulic cements should not be allowed for use in concrete pavements. It is anticipated that this research study will result in a WSDOT cost savings of approximately $250,000 (see Appendix 10).

Corrosion Resistance Study. A study, conducted by Caltrans/University of California – Berkeley for determining the corrosion resistance of carbon steel, stainless steel hollow, epoxy coated, and stainless steel clad dowel bars (though this study can also be applied to tie bars and bridge steel) has concluded that the epoxy coated and carbon steel dowel bars corrode, while the stainless steel clad and stainless steel hollow bars show no signs of corrosion. WSDOT has recently submitted half of a stainless steel clad dowel bar cage for determination of corrosion potential at the ends of the dowel bars as well as the connection to the dowel bar cage. In addition, WSDOT will be exhuming (summer 2003) a 10-year-old dowel bar retrofitted transverse joint and shipping it to University of California – Berkeley for determination of the corrosion extent. It is anticipated that this research study will result in a WSDOT cost savings of approximately $15,000,000 (see Appendix 11).

Traffic Simulation Software. The traffic simulation software is an effective tool for analyzing transportation networks, in design, planning or operation studies. The *Paramics* software, one the leading products available worldwide, can model large networks in a fine level of detail, by considering individual vehicles and replicating the effects of congestion, variable driver behaviors and the impact of different traffic management and information systems. The traffic simulation software can play an important role in the process of planning and evaluating freeway construction activities. Two on-going projects funded by Caltrans, on I-710 in Long Beach (District 7) and I-15 in San Bernardino (District 8), have illustrated the benefits of using *Paramics* as part of the traffic analysis. The simulated areas cover the freeway construction zone and a number of other roadways potentially affected by route diversion during reconstruction. In addition to the impressive visualization capabilities offered by the graphical user interface, the traffic simulation software provides a powerful analysis tool to quickly and accurately (after calibration) evaluate a large number of freeway reconstruction scenarios and associated traffic management plans and address critical questions such as:

- How should mainline freeway and ramp closures be planned to minimize the traffic delays caused by the reconstruction activities?
- What kind of traffic control and information strategies should be included in the Traffic Management Plan to minimize the overall traffic delay during the reconstruction?
- What is the quantitative traffic impact of construction on the freeway and surrounding area?

It is anticipated that this research study will result in a WSDOT cost savings of approximately $500,000 (see Appendix 12).

Moisture Susceptibility. This Caltrans/University of California – Berkeley study will investigate the effect of different variables (materials, pavement structure, construction quality, traffic, and climate) on the field performance of hot-mix asphalt pavements with respect to moisture damage; examine the feasibility of defining moisture sensitivity using tests related to pavement performance (including rutting and fatigue); if possible, develop laboratory test

procedures that will better predict field performance. It is anticipated that this research study will result in a WSDOT cost savings of approximately $5,000,000 (see Appendix 13).

NATIONAL CENTER FOR ASPHALT TECHNOLOGY (NCAT)

The National Center for Asphalt Technology (NCAT) was created in 1986 through an agreement between the National Asphalt Pavement Association Education Foundation and Auburn University. The following information is a result of an SPTC meeting held at NCAT in September 2002. It is envisioned that the SPTC and NCAT will continue to provide valuable technology exchanges in the area of hot mix asphalt pavement.

Test Track. The NCAT Test Track is the largest research project underway at NCAT. The Test Track, consisting of 26 test sections on the tangents and 20 test sections on the curves, will be subjected to 10 million ESALs over a period of two years. The following are specific mix attributes whose rutting (permanent deformation) performance will be compared on the Test Track.

- Coarse-graded, fine-graded and through the restricted zone gradation of Superpave mixes
- Neat versus modified asphalt binder at optimum asphalt binder at optimum asphalt content as well as optimum plus 0.5 percent
- Stone matrix asphalt (SMA) versus Superpave mix using granite aggregate
- 12.5 mm versus 9.5 mm nominal maximum size Superpave mixes

The mixtures have been tested by various laboratory performance tests, which will be correlated with actual field performance to determine the best test method(s) for predicting rutting performance. The rut depth developed so far in the test sections ranges from 0.5 to 6.2 mm. It is expected that the Test Track will be subjected to the target of 10 million ESALs by November 2002.

National Center for Asphalt Technology Test Track

Permeability of Asphalt Concrete Pavements. Historically, it has been believed that achieving densities in HMA of between 3 and 8% air voids would result in a pavement that would not be susceptible to water damage, oxidation, raveling, and cracking. There is some indication from recent studies that coarse-graded Superpave mixes can be excessively permeable to water at in-place air voids less than 8 percent due to larger void sizes which increase the chance of inter-connection of the void spaces. NCAT conducted a study to evaluate the relationship between in-

place air voids, lift thickness, and permeability on 23 HMA construction projects. Field permeability tests were conducted using a simple device built at NCAT and cores were taken at those same sites to determine density. Results showed a good relationship between permeability (measured in the field and lab) and pavement density. Both the nominal maximum aggregate size (NMAS) and the lift thickness affected the permeability-density relationship. As the lift thickness of a given pavement increases, permeability decreases at a given density level.

The performance of the NCAT Test Track also illustrated that rigid adherence to specifications and excellent construction practices will result in excellent pavements in spite of the use of multiple mix designs, aggregates, and binders. This should benefit WSDOT in the training area for both inspectors and contractor's personnel.

It is anticipated that this research study will result in a WSDOT cost (due to early pavement failure) of approximately $18,000,000 (see Appendix 14).

OTHER SHARED RESEARCH

Concrete Tining. The greatest benefit of concrete tining was the directing of skidding vehicles in a straight path rather than off of the roadway. However, tining led to problems in the durability of the wearing surface of the concrete pavement. TxDOT noted greater abrasion loss and increased spalling of the surface when tining was used. Mn/DOT noted that noise generated by the closely spaced tining was the primary reason for the change back to the non-tined surface treatment specification. The driving force behind this change was local neighborhood associations and the state legislature. Mn/DOT found longitudinal tining to be significantly quieter than transverse tining and the frequency generated by the tining to be more important than the general dB level. Research has shown that there is a greater loss of moisture from the concrete during curing in tined pavements because of the delay required for the concrete to reach the point where tining can be done and the curing compound applied. The additional surface area exposed by the tining also increases the amount of moisture lost through evaporation. Research into accident rates on carpet drag versus tined pavements has shown no statistically significant difference between the two processes. Research has also shown that tining is detrimental to moisture loss and abrasion resistance which both affect long-term performance (see Appendix 15).

Prestressed Concrete. TxDOT has constructed a test section of precast, prestressed, post-tensioned PCCP near Georgetown, Texas. The test section is on a frontage road of I-35. The existing roadway was prepared by placing a 2-inch leveling course on the existing subgrade or existing pavement. The precast members were built in 10-foot long segments that were 16, 20, or 36 feet wide. TxDOT noted that the casting beds were very expensive to build. The segments were prestressed in the transverse direction at the casting plant and post-tensioned in the longitudinal direction once they were placed on the grade. Special sections were built to serve as anchors and others to serve as post-tensioning points. Blockouts were used in both of these special sections that were filled with fast setting concrete mix after the post-tensioning was completed. TxDOT estimates that the 8-inch thick test pavement was equivalent to 14 inches of continuously reinforced concrete, (see Appendix 16).

Table 1. SUMMARY OF BENEFITS (1999-2003)

Title	WSDOT Cost	Others Cost	WSDOT Benefit
Constructability analysis software	$49,200	$147,595	$5,000,000
Improved pavement field characterization	$6,200	$18,675	$200,000
Longitudinal joint	$12,200	$103,163	$4,000,000
HMA View	$50,000	$60,000	$3,000,000
Dowel bar retrofit	$5,000	$750,000	$15,000,000
Climatic database	$890	$100,000	$100,000
Multi-Cool software	$0	$100,000	$1,000,000
Asphalt treated permeable base	$0	$100,000	$500,000
Tack coat benefits	$0	-	$5,000,000
Hydraulic cements	$0	$250,000	$250,000
Corrosion resistance	$0	-	$15,000,000
Traffic Simulation software	$0	$250,000	$500,000
Moisture Susceptibility	$8,000	$500,000	$5,000,000
Permeability of asphalt concrete pavements	$0	Unknown	$18,000,000
Concrete tining	$0	Unknown	N/A
Prestressed concrete	$0	$1,000,000	N/A
Travel Expenses*	$33,000	$42,000	N/A
TOTALS	$164,490	$3,574,323	$67,550,000

* WSDOT travel expenses to the various SPTC meetings, which began in July of 1999, are approximately $33,000 (approximately $8,000 per year). The other states have spent approximately $42,000 on travel.

Appendix 1
Constructability Analysis Software

This software has been used on several projects in the Northwest Region (I-5 southbound vicinity of Federal Way and I-5 convention center) to assist the Project Office in determining the necessary lane closure time for reconstruction of portland cement concrete pavement. For the I-5 Southbound vicinity of Federal Way project, this software indicated that a two weekend closure would require a total of 124 hours to complete, while nighttime closures would require 22 nights at 14 hours per night or a total of 308 hours. This results in an estimated user delay cost savings of approximately $14,000,000 (or approximately $4,500,000 per lane mile) on this three-lane mile project.

This software was developed for a total cost of $196,795 (WSDOT contribution of $49,200). Current projection on the number of lane-miles of concrete pavement that needs reconstruction, statewide, is approximately 1000 lane-miles (over the next 10 years). These miles are located on interstate pavements that currently carry 50,000 to 280,000 ADT. The ability to analyze these reconstruction projects and define the lane closures impacts can result in a user cost savings of over $450,000,000 per year (assuming reconstruction of 100 miles per year). The cost savings for WSDOT for identifying scheduling scenarios and working day requirements is approximately $5,000,000.

Appendix 2
Improved Pavement Field Characterization

The total cost for this research project was $24,875, of which WSDOT's contribution was $6,200. The primary impact this study will have for WSDOT is the improved characterization of the existing pavement structure, required material properties, and measurement techniques. This research project provides WSDOT Region Materials and pavement design engineers extend knowledge on pavement field characterization, which is critical for the determination of the appropriate pavement rehabilitation alternative. The total cost savings of this project is approximately $200,000.

Appendix 3
Longitudinal Joint Compaction in Hot-Mix Asphalt Pavement

This study originated with the Texas Department of Transportation to evaluate the extent and the potential causes of failing longitudinal joints on TxDOT roadways. During a SPTC meeting, the study was proposed to California, Minnesota, and Washington, of which all states contributed additional funds to evaluate longitudinal joints in each of their states. On Washington roadways, this distress occurs on approximately 10 percent of overlay projects constructed annually (approximately 60 lane miles). This distress results in a four to six year reduction of pavement life. The total cost of this research project was $115,363, with WSDOT contribution of $12,200 for material testing.

The average pavement overlay life in Washington state is 12.5 years, therefore, on average, these roadway sections are only experiencing pavement lives of 6 to 8 years before rehabilitation is required. Therefore, the estimated benefit of this research is approximately $4,000,000. This cost is based on an average overlay cost of $150,000 per lane mile, a five-year reduction in pavement life and impacts of 60 lane miles annually. The implementation of this research will result in a change to the standard specification for longitudinal joint construction.

Appendix 4
HMA View

The total cost for this research project was $110,000, with WSDOT contributing $50,000. HMA View will dramatically improve WSDOT and Contractors ability to review and analyze mix related issues and long-term effects of asphalt concrete overlay projects. The immediate impacts of this software will allow for improvements in project troubleshooting and analysis. The estimated total cost savings of this research project is $3,000,000.

Appendix 5
Dowel Bar Retrofit

A key role for WSDOT in this research is the oversight of the dowel bar retrofit test section construction. The contractor had limited experience and the researchers from the University of California Berkeley had no experience with dowel bar retrofit construction. Without the presence of WSDOT personnel, the construction of the dowel bar retrofit test section might not have been comparable to actual dowel bar retrofit construction in Washington State. The integrity of the results could have been jeopardized without WSDOT presence to provide technical expertise.

The total cost for this research project was $750,000, all of which are costs covered by Caltrans. WSDOT contribution to this project was only $5,000 for travel expenses and wages during construction of the test section. As stated earlier, the main benefit of this research project for Washington is the validation of dowel bar retrofit performance (how many years will dowel bar retrofit extend pavement life), validation of where dowel bar retrofit is applicable (what specific pavement condition, i.e. faulting and cracking, would prohibit the use of dowel bar retrofit), and determination of how dowel bar retrofit will fail.

Though WSDOT has determined that dowel bar retrofit is a viable option for rehabilitating our concrete pavements, the ability to refine where and when dowel bar retrofit is appropriate will provide valuable insight and cost savings. The estimated costs savings of this research project is $15,000,000.

Appendix 6
Climatic Database

This software will significantly enhance the pavement design process by providing additional information on the impact of the environment (specifically related to frost depth) and is necessary input for the new 2002 Pavement Design Guide being developed by AASHTO. In addition, it is envisioned that this software will have several other applications, for example, an improved procedure for identifying appropriate construction windows for both asphalt and concrete pavements and the optimum timing for opening to traffic on concrete pavements.

The total cost of this research project is approximately $100,000, all of which are Caltrans costs. The WSDOT associated costs for this research were only $890, which was for travel and wages to attend a meeting to brainstorm database output values. Since this research project will primarily impact design features, the gained knowledge of this study is difficult to assign an exact cost savings. However, if WSDOT had to do this research, a similar cost of $100,000 would need to have been spent.

Appendix 7
Multi-Cool Software

This software is an analysis tool that helps to determine the time to place asphalt concrete pavement. Since temperature is directly related to the ability to obtain adequate compaction, it is valuable to WSDOT and Contractors to determine limiting criteria when paving early or late season, nighttime paving, in cool temperatures, in winding conditions, etc.

The costs for this research study were approximately $100,000 (Minnesota and Caltrans funded research), of which WSDOT has not contributed any research funds. It is estimated that this research will provide WSDOT with an estimated costs savings of $1,000,000.

Appendix 8
Asphalt Treated Permeable Base

The total cost of this research was approximately $100,000, all of which was Caltrans funding. WSDOT contributed no costs for this research study. Even though WSDOT stopped specifying asphalt treated permeable base in the early 1990's, the knowledge that this decision was the correct decision has resulted in substantial cost savings associated with future repair and rehabilitation costs. From the Caltrans study, it has been determined that asphalt treated permeable base (and asphalt treated base) are susceptible to stripping in later years of the pavement life. Stripping in these pavements is primarily related to the lower asphalt content required for these mixes. WSDOT has offset the stripping problem by requiring either an ACP Class E or Superpave ¾ inch mix for asphalt concrete bases. As asphalt concrete pavement strips, critical structural support is jeopardized and the pavement structure will begin to show signs of fatigue cracking (see Photos 1 and 2). Unfortunately, the appropriate rehabilitation strategy for these pavements is a thick asphalt overlay (> 3 inches), extensive pavement repair, or complete reconstruction (depending on the traffic loading, some of these pavement structures could be rehabilitated with full-depth reclamation or cold in-place recycling). The estimated cost savings of this research project is $500,000.

Photo 1. Fatigue damage due to stripping of underlying asphalt concrete pavement

Photo 2. Fatigue damage due to stripping of underlying asphalt concrete pavement.

Appendix 9
Tack Coat Benefits

The exact cost of this research study is unknown since it was one of the findings from a much larger study conducted by University of California – Berkeley. However, it does indicate the benefit and critical value that is added from appropriately and adequately applied tack coat (see Photos 3 and 4). Even though the use of tack coat has been a WSDOT specification for a number of years, it does provide reassurance that tack coat is critical to asphalt pavement performance. The benefits of this research will result in an estimated costs savings of $5,000,000.

Photo 3. Well placed tack coat

Photo 4. Poorly placed tack coat

Appendix 10
Hydraulic Cements

The total research cost for this project was approximately $250,000, all of which was funded by Caltrans. The cost savings for WSDOT can be equated to the cost for conducting a similar research project in Washington State. Therefore, the costs savings for WSDOT would be $250,000.

Appendix 11
Corrosion Resistance Study

WSDOT has demonstrated that the concrete pavements constructed in the late 1950's to early 1960's are able to obtain a 40-year or more pavement life as long as joint faulting can be overcome. The ability to provide adequate joint design to minimize joint faulting is being addressed by including dowel bars (1-1/2 by 18") at every transverse joint. However, the use of epoxy coated dowel bars does not necessarily ensure that a 40-year performance life will be obtained. Minnesota has observed that the corrosion of epoxy coated dowel bars occurs within 15 to 20 years. Therefore, it is desirable to obtain and use dowel bars that have the ability to offset the effects of corrosion. WSDOT is recommending the use of stainless steel clad dowel bars on all newly constructed concrete pavements.

In addition, Caltrans is evaluating the various materials for dowel bars (fiber, epoxy coated, and stainless steel clad) for corrosion resistance. As WSDOT begins to reconstruct many of the urban interstate concrete pavements, there is a need to have long-lived pavements (minimal future traffic impacts). Therefore, it is critical that WSDOT uses dowel bars that will obtain 50 plus year lives without showing signs of corrosion.

WSDOT has contributed $600 (shipping costs) to this study for the evaluation of a stainless steel clad dowel bar cage taken from a WSDOT construction project on Interstate 5.

The dowel bar corrosion research study significantly impacts WSDOT's ability to obtain long-lived concrete pavements. Since this is a critical design feature, the exact cost savings is difficult to quantify. However, the knowledge and verification of the benefits of stainless steel clad dowel bars is a valuable benefit that has an associated cost of at least $15,000,000.

Appendix 12
Traffic Simulation Software

The total research cost for this project was approximately $250,000, all of which was funded by Caltrans. The cost savings for WSDOT would be $500,000.

Appendix 13
Moisture Susceptibility

The key role for WSDOT in this research is to provide the University of California – Berkeley information on pavement projects that are experiencing good and poor performance related to moisture susceptibility. This information includes hot-mix asphalt core samples, aggregate samples, pavement management data (specifically pavement performance), and construction data.

The total cost for this research project is approximately $500,000, all of which are costs covered by Caltrans. WSDOT contribution to this project is approximately $8,000 for travel expenses and wages for information gathering, sampling and coring.

WSDOT has numerous aggregate sources that are impacted by moisture susceptibility. The current test procedure (Modified Lottman) has been questioned in the past on its ability to predict moisture susceptibility impacts as they related to pavement performance. This study will provide the link between laboratory testing and field performance. The potential impact of this study is better definition of moisture susceptibility and potential changes in the approval of statewide aggregate sources. The estimated costs savings of this research project is $5,000,000.

Appendix 14
Permeability of Asphalt Pavements

The total research cost for this project is difficult to determine since it incorporates a number of state DOT research projects as well as research conducted at the National Center for Asphalt Technology. However, the cost savings for WSDOT can be equated to the knowledge gained for the construction requirements for ensuring a non-permeable driving surface. This research will impact WSDOT specifications for placement of a specific class of asphalt concrete pavement (Superpave ¾ inch and larger). The specification change will then ensure that this type of asphalt concrete pavement will obtain the required performance life of 15 years. Based on current WSDOT specifications, this type of mix would be compacted to 91 percent of maximum density, where research by others has indicated that this class of mix should be compacted to 94 percent of maximum density. This change of 3 percent would reflect a 30 to 50 percent reduction in pavement life. Since 1995, WSDOT has constructed approximately 100 Superpave projects, 22 of these projects have been constructed using the ¾ inch Superpave mix. Since these 22 projects were placed with the current compaction requirement of 91 percent, using the above assumption of a loss of 30 percent of pavement life, relates to a pavement life of 10.5 years rather than the expected life of 15 years. For the 22 projects constructed to date with ¾ inch Superpave mix (approximately 400 lane miles) and average overlay cost of $150,000 per lane mile results in an estimated cost (due to reduced pavement life) of $18,000,000.

Appendix 15
Concrete Tining

The total research cost for this project is difficult to determine since it incorporates a number of state DOT research projects. However, the cost savings for WSDOT can be related to a modification to the current tining specification, which would no longer require the use of a specialized machine (see Photos 5 and 6), thereby slightly reducing the unit cost for concrete pavement. Though WSDOT has not seen damage to its concrete pavements due to tining, we have seen dramatic reduction of the tining benefits in a matter of two to three years due to studded tire wear (see Photos 7 and 8).

Photo 5. Tining concrete pavement

Photo 6. Close-up of tined surface

Photo 7. Hwy 101, Ukiah, California, tining still apparent after 25+ years

Photo 8. SR-395, Ritzville vicinity, tining non-existent in the wheel paths after 8 years.

Appendix 16
Prestressed Concrete

This type of pavement construction is not envisioned to be a viable pavement rehabilitation option due to the high intensity of construction, traffic control and associated costs. In addition, this type of construction was envisioned to reduce the required construction time, but the research indicated that construction time was approximately the same as using fast setting concrete. Therefore, the value gained from this research is the realization of what not to do in Washington State. Texas DOT has spent close to $5,000,000 (over 20 years) for this research study.